

THE EFFECTIVENESS OF ESCAPE HATCH ILLUMINATION AS AN AID
TO EGRESS FROM A SUBMERGED HELICOPTER: Final Report

by

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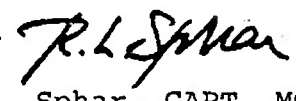
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ABSTRACT

Simulation procedures were used to evaluate the effectiveness of internal escape hatch illumination as an aid to egress from a helicopter which has crashed, submerged, and inverted in water. Simulations were conducted in the daytime and at night. More rapid egress occurred when the escape hatches were illuminated than when they were not. There was no significant difference between the speeds of night and day egress under either lighting condition. Also evaluated was the utility of an underwater breathing device. The use of escape hatch illumination and the provision of an underwater breathing device is supported by the results of this study.

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INTRODUCTION

This report evaluates the effectiveness of internal lights as an aid to escape from a helicopter which has crashed, submerged, and inverted in water. The purpose of the study was to determine, through simulation procedures, the ease of egress from the submerged inverted helicopter with illuminated and non-illuminated hatches.

METHOD

Subjects

The subjects in this study were 24 divers from Underwater Demolition Team 21 from Little Creek, Virginia. These divers were highly trained and capable of coping with a variety of stressful and unusual underwater environmental conditions. The subjects were divided into four groups. One of these participated in the study on each of four consecutive weeks. Each group was randomly divided into two, three-man teams.

Personnel and Equipment

Simulation was accomplished through the use of an H-3 helicopter hulk modified so that it could be easily flooded with water, inverted, raised, and drained. Manipulation and inversion of the simulator was accomplished by means of a double hook crane. As illustrated in Figure 1, the simulator was fitted with three troop seats. Each of the three windows used

as an escape hatch (Figure 1) was fitted with electroluminescent lights at the top and sides. The lights (Figure 2) were fitted with underwater connectors, had an illuminated area 15 inches high and 1.5 inches wide (38.1 centimeters x 3.81 centimeters), were powered from shore, and were operated at 1000 Hertz and 120 volts.¹ For purposes of data acquisition, each of the seats and windows was fitted with underwater switches. Seat switches were manually activated and window switches were saltwater activated. Data acquisition was accomplished by means of a specially designed system using a NOVA 1220 computer. Signals from the switches were transmitted to the surface by underwater cables. Communication between the diving supervisor and the safety personnel in the water was maintained with a hydrophone system. Subjects wore scuba gear which, for purposes of subject identification, was color coded through the use of red, white, and black caps. During night simulation, necessary surface illumination was provided by two banks of flood lights.

All subjects were provided with a prototype helicopter breathing device.² This device, shown in Figure 3, consists of an inner and outer coil of stainless steel tubing, weighs 3.6 pounds (1.65 kilograms), and is 5.5 inches high, 5 inches wide and 2.5 inches deep (2.17 centimeters x 1.97 centimeters x .98 centimeters). When pressurized to 5000 pounds per square inch, it provided approximately 4.5 minutes

of air under non-stressful swimming conditions at a depth of approximately 10 feet (3 meters).

A minimum of three qualified safety divers were in the water during all operations. In addition to the experimenters, shore personnel consisted of a diving officer, a medical supervisor, diving supervisor, data recorders, and other support personnel. An ambulance was on standby status at all times.

Design and Procedure

Simulations were conducted in the Thames River at the Naval Submarine Base New London, Groton, Connecticut. Water depth was 20 feet (6.1 meters), water temperature averaged 65° Fahrenheit (18.3° celsius), and underwater visibility was 6 to 8 feet (approximately 2 - 2.5 meters). Daytime simulations were conducted at midafternoon, and night simulations were performed as soon as it was dark enough to require artificial illumination.

Primary Study: The experimental design is summarized in Table 1. Each 6-man group was subjected to the experimental procedure for three days during the week it participated in the experiment. To provide for maximum safety, a daylight simulation preceded night simulations. Within these conditions, a randomly selected team completed 2 lights-on and 2 no-light runs for a total of 24 runs, before the second team began its runs. The order of the light/no-light conditions was random.

Three escape routes (Figure 1) were designated and coded as

follows: Seat 1 Window 1 - Red; Seat 2 Window 2 - White; Seat 3 Window 3 - Black. Subjects were randomly assigned to a seat which they occupied at the start of each trial.

On the morning of the first experimental dive, all subjects received a briefing during which the details of the study were explained and seat assignments were given out. Prior to the first simulation, subjects participated in an in-water familiarization run. Subjects were seated in the hulk which was subsequently submerged but not inverted. With this exception, conditions were the same as for actual simulation runs.

The procedure on the simulation runs was as follows. The helicopter was positioned on the water approximately 50 feet (about 15 meters) from shore. After the safety divers had positioned themselves on either side of the hulk, the subjects entered the water and took their assigned seats in the helicopter. Subjects, assisted by the safety divers, strapped themselves in their seats and checked the data switches. Subjects held the manually operated switches in their hand. Upon receiving a signal from the safety divers that subjects were ready and all data switches were set, the diving supervisor simultaneously signalled (a) the crane operator to begin submersion and inversion of the helicopter, and (b) the experimenter to initiate data recording. When completely submerged and inverted, the bottom of the helicopter was just below the surface of the water. Subjects remained strapped to their seats

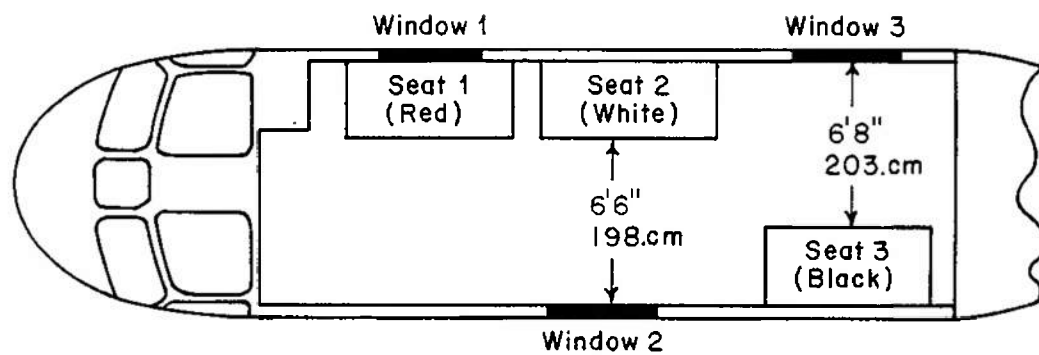


Figure 1. Interior configuration of the H-3 simulator showing egress routes and seat and window coding. Designated escape routes are Red-seat 1-window 1, White-seat 2-window 2, Black-seat 3-window 3.

Table 1
Experimental Design

Group	Window	Day		Night	
		Lights	No Lights	Lights	No Lights
1	1	1,2*	1,2	1,2	1,2
	2	3,4	3,4	3,4	3,4
	3	5,6	5,6	5,6	5,6
2	1	7,8	7,8	7,8	7,8
	2	9,10	9,10	9,10	9,10
	3	11,12	11,12	11,12	11,12
3	1	13,14	13,14	13,14	13,14
	2	15,16	15,16	15,16	15,16
	3	17,18	17,18	17,18	17,18
4	1	19,20	19,20	19,20	19,20
	2	21,22	21,22	21,22	21,22
	3	23,24	23,24	23,24	23,24

*Subject number. Within each group, odd numbers designate subjects on Team 1 and even numbers subjects on Team 2. Each subject made two runs under each condition. A daylight run preceded each night run.

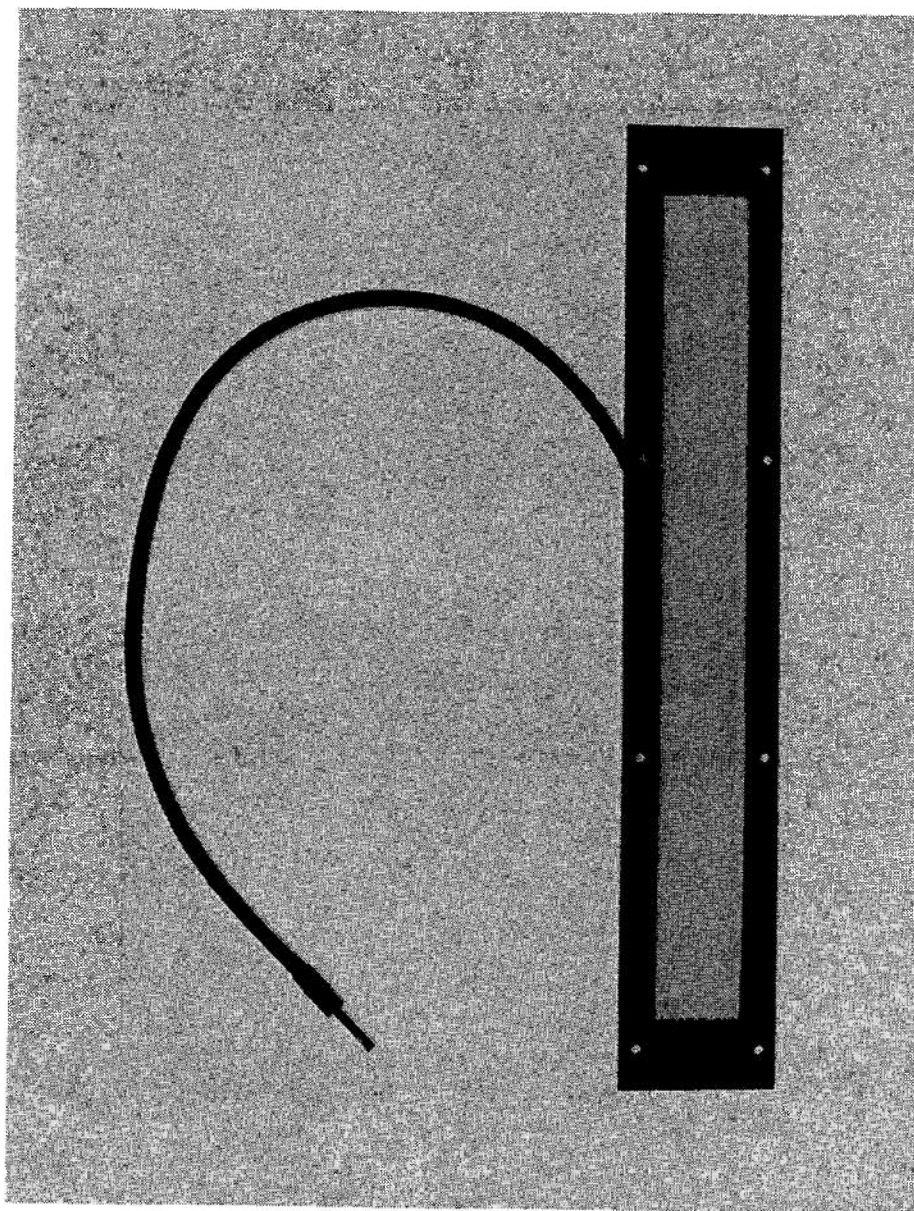


Figure 2. Electroluminescent light fitted with an underwater connector.

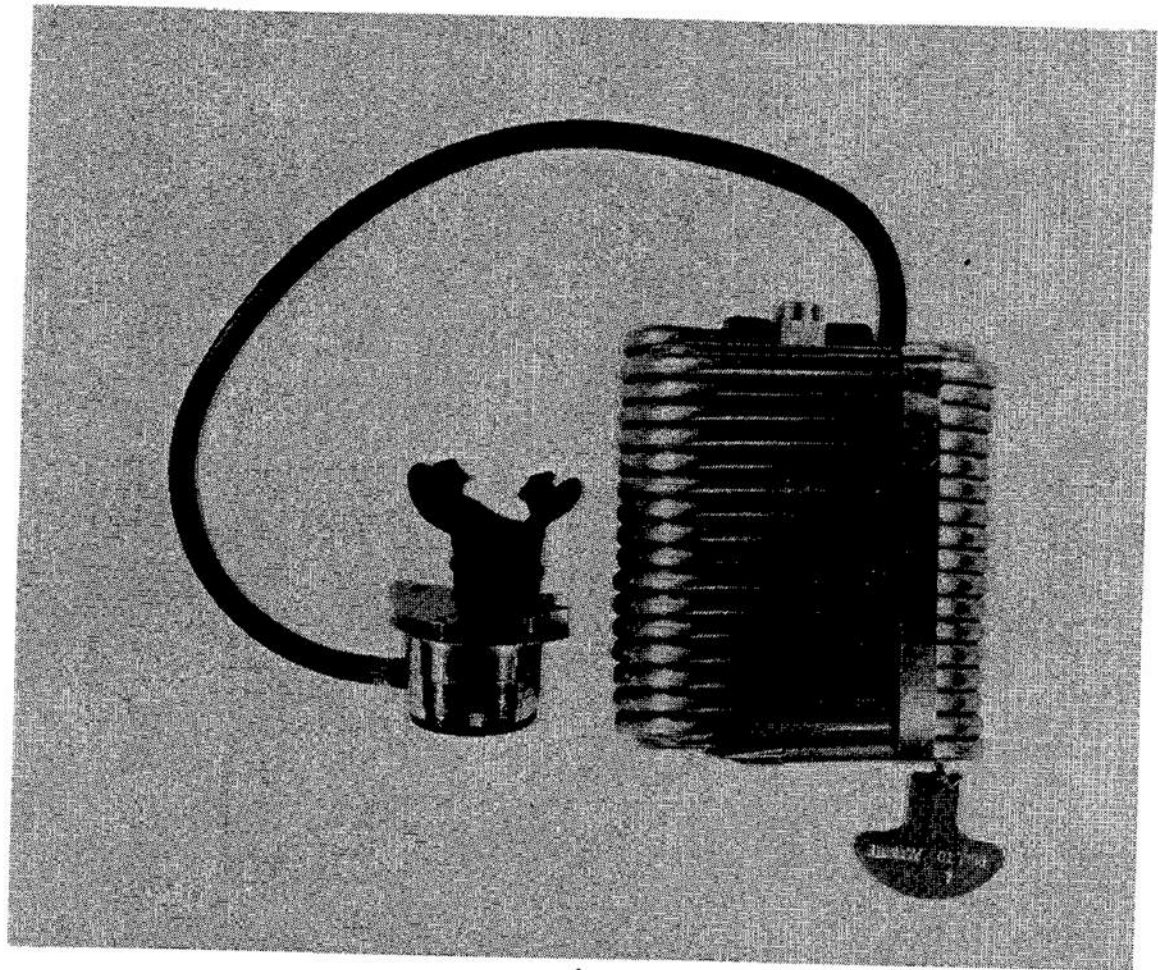


Figure 3. Prototype helicopter escape breathing device.

in the inverted hulk until the onrush of water had ceased. They began their egress by simultaneously releasing their seat belt and activating the manual switch. They then made their way to the designated window and exited to the surface. While exiting the window, subjects broke a connection which activated the saltwater switch. As each subject arrived at the surface, the experimenter signalled the computer by a switch closure.

A complete cycle, consisting of submersion, inversion, and return of the H-3 to the surface, could normally be accomplished in 45 seconds. If any subject failed to appear on the surface within one minute after the initiation of the cycle, divers were considered to be having difficulty and the supervisor signalled the crane operator to raise the helicopter to the surface.

During simulations with activated window lights, these lights were turned on from the surface as soon as the bottom of the window was covered by water. Flood lights were used to illuminate the surface of the water at night. The flood lights were turned off during simulation since they tended to illuminate the interior of the submerged helicopter.

The A-State Scale of the State-Trait Anxiety Inventory (STAI) (Spielberger, et al., 1970), and a modified Epstein and Fenz (1965) anxiety scale were administered to the subjects each day prior to and after each series of day and night runs. The STAI A-State consists of 20

statements requiring the subject to indicate on a four-point scale how he feels at a particular moment in time. The range of possible scores varies from a minimum of 20 to a maximum score of 80. The Epstein-Fenz scale was designated as the Helicopter Rescue Questionnaire (HRQ). It consisted of 14 items (Table 2) relevant to the subject's feelings during four periods of the escape cycle. A subject indicated what the most fear arousing situation ever encountered in his adult life was, assigned this a value of 10, and then rated his feelings of anxiety relative to this standard. The purpose of the scales was to obtain a measure of the relative levels of anxiety for each series of day and night runs. At the completion of all of the evaluation runs, a questionnaire asking about the subjects' reactions to the lights, breathing device, and other aspects of the study was administered.

Secondary Studies: In addition to the major body of data collected, brief evaluations were made to determine possible effects on escape time of the presence of more than 6 men during egress and to determine whether egress times might be affected if the escapees had been dressed in full flight gear. These evaluations were run after the primary evaluations had been completed. Insufficient data were collected to make rigid statistical evaluation possible; however, comparisons of these data with those obtained from the primary study are meaningful.

The procedure used for the full

Table 2
Helicopter Rescue Questionnaire Items¹

Escape Period	Item Number	Item
Pre-escape	1	Before the experimental trial began
	2	Waiting to board the craft
	3	Boarding the craft
	4	On board waiting for descent
Submersion & Inversion	5	While craft descends
	6	While craft sinks
	7	While craft inverts
Escape	8	At time of go signal
	9	Initiation of escape (releasing seat belt, leaving seat)
	10	While finding window
	11	During escape (exiting through window)
Post-escape	12	Reaching surface
	13	Waiting for next trial
	14	Now

¹For each item a subject rated his feelings of anxiety on a scale of 0-10 relative to a subjective standard.

flight suit evaluation was identical to that used in the primary study. Data was collected for one of the four groups (Group 3). All escapes were made in daylight under no light conditions.

For the 6-man runs, the procedure was modified as follows. The two teams were combined into a single 6-man team. Two subjects were assigned to each escape route and were seated next to each other. Seat and window escape times were recorded only for the first man to exit. Surface times were obtained for all six subjects. The latter procedure was required because the data recording system had been designed for three man evaluations and could not be readily modified for six man escapes. Six man runs were obtained for Groups 2 and 3. Because of equipment failure, only lights off data were available for Group 2. Thus, Group 2 made a total of six no lights runs, Group 3 made three no light runs and three lights on runs. All runs were made during daylight.

RESULTS

Three sets of data were obtained: time release of the seat belt; time of activation of the window switch; time of arrival on surface.

Primary Study: The data for the first experimental day will be considered first and will then be discussed in relation to the data for days two and three. These data were selected as being closest to what might be obtained from an actual helicopter crash at sea. Subjects undergoing the first day simulation would have

had a minimum of experience with egress from the H-3. Additionally, as may be seen in Figures 4 and 5, the data from our anxiety measures indicates the highest level of anxiety among the subjects occurred on the first day. The measure of egress time utilized was the time elapsed between release of the seat belt (activation of the manual switch) and the initiation of window egress (activation of the salt-water switch). The measure for a subject was taken as the average of his times over the two replications of a condition. If a subject failed to initiate window egress or took longer than 60 seconds to do so, he was assigned an egress time of 60 seconds.

Analysis of variance of the data revealed that only two variables showed statistically significant effects: windows (time of egress from the various hatches), and the presence or absence of window lighting. The former was significant at less than the .01 level, and the latter at less than the .05 level.

The mean escape times for the subjects on Day 1 have been collapsed over groups and are presented in Table 3. Escape times were most rapid for Window 2 and the slowest for Window 1. More rapid egress occurred when the windows were illuminated than when they were not. There was no significant difference between the speed of night and day egress under either the light or no-light conditions.

As may be seen in Table 3, the results for experimental trials on Days 2 and 3 parallel those obtained for the first day.

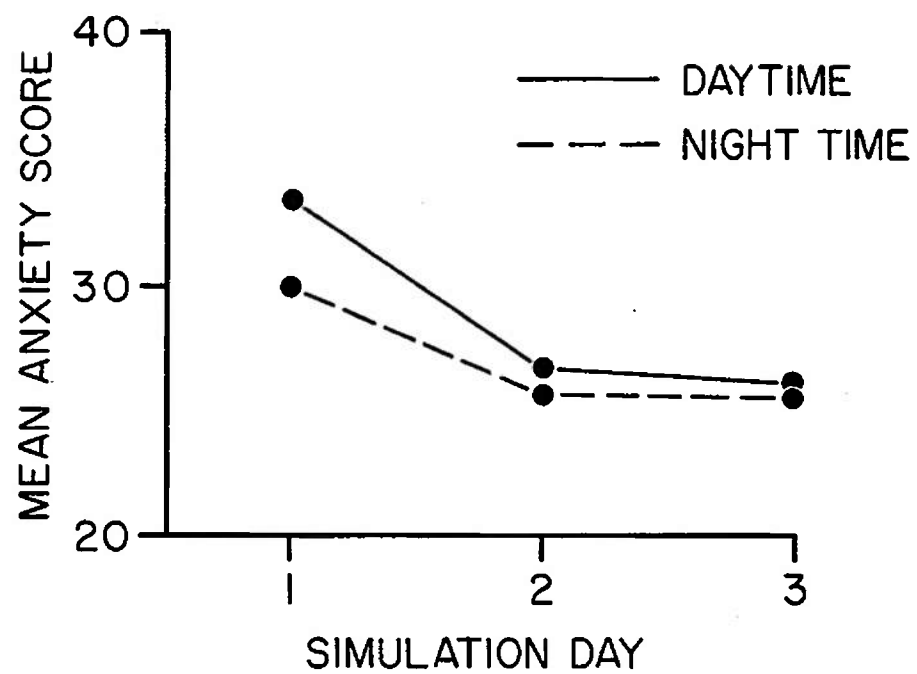


Figure 4. Mean daytime and nighttime post-simulation anxiety scores for each day as measured by the STAI. The possible range of scores is 20-80.

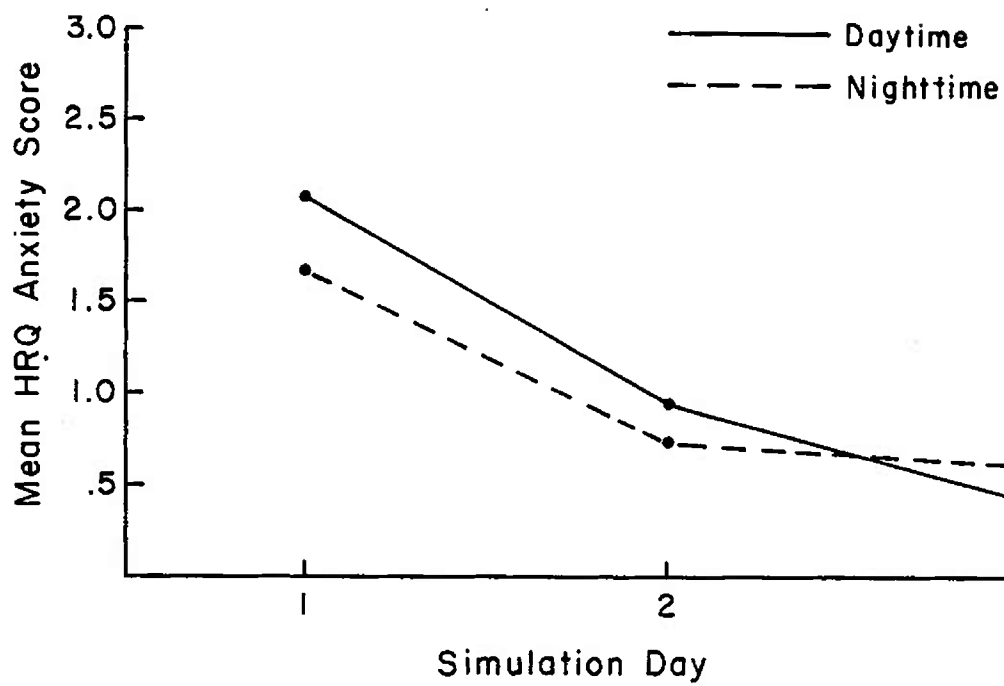


Figure 5. Mean daytime and nighttime post-simulation anxiety scores for each day as measured by the HRQ on a scale of 0-10.

Table 3

Mean Day and Night Egress Time* by Days for Each Window With and Without Illumination

	DAY ONE				Mean	DAY TWO				
	Lights		No Lights			Lights		No Lights		
	Day	Night	Day	Night		Day	Night	Day	Night	
Window										
1	10.27	6.84	16.30	11.17	11.15	6.96	10.40	8.15	7.59	8.28
2	4.32	4.51	4.08	7.98	5.22	4.61	4.37	3.91	3.91	4.20
3	5.33	5.63	13.30	8.66	8.23	5.34	8.68	9.31	9.32	8.16
Mean	6.15		10.25		8.20	6.73		7.03		6.88

Window	DAY THREE				Mean	DAY FOUR				
	Lights		No Lights			Lights		No Lights		
	Day	Night	Day	Night		Day	Night	Day	Night	
1	6.21	6.37	7.48	7.57	6.91	7.81	7.87	10.64	8.87	8.78
2	3.87	4.34	4.62	4.78	4.40	4.27	4.41	4.20	5.56	4.61
3	4.38	5.99	5.62	9.95	6.49	5.02	6.77	9.41	9.31	7.63
Mean	5.18		6.67		5.93	6.03		7.98		7.01

*Times are in seconds

Escape time with lights on is less than escape time without the lights. The most rapid egress is made from Window 2 with egress times from Window 3 being faster than those from Window 1. There was no overall difference in escape times between day and night egresses. There is a general trend in the direction of increased speed of egress over days indicating that training and experience can reduce egress times even for experienced divers.

Secondary Studies: The results for the 6-man runs and the flight suit evaluation are summarized in Tables 4 and 5. For the 6-man runs, the data points represent the seat to window egress times for the first man to exit by a given escape route. For Group 2, the measure obtained is the average time for six replications of the no lights condition, and for Group 3, the average time for three replications of each condition. The measures for the flight suit evaluation are the same as those obtained for the no lights condition in the primary study.

As previously indicated, tests of statistical significance were not obtained for the data of the secondary studies. Window 1 was the most difficult to egress from and Window 2 permitted the most rapid egress. For the 6-man runs, escape time with lights was more rapid than with no lights.

DISCUSSION

The subjects in this study were selected because of their training and competence in the water. These characteristics, while enhancing safety, may have

depressed the level of anxiety experienced by the subjects and reduced the magnitude of the difference in egress time with illuminated and non-illuminated hatches. This is particularly true for the Day 1 data. Since the subjects were exceptionally uniform in characteristics related to underwater egress, it is not surprising that there was no significant difference in the performance of the four groups. These factors must be taken into consideration in generalizing these findings to escape by less highly trained passengers and crew members.

The variables resulting in the slowest egress time for Window 1 are readily apparent. Although Subject 1 was seated directly in front of the window and should have had no difficulty locating it, it was necessary for him to remove the back support from the window in order to make an egress, and to exit from the window without striking a sponson support.

Subjects' responses on the evaluation questionnaire showed strong support for the use of the lights, particularly at night. When asked to evaluate ease of night escape on a scale of 1 (exceptionally easy) to 6 (exceptionally difficult), their mean rating with lights-on was 1.5; with lights-off the rating was 4.6.

There were 16 recorded instances when subjects became disoriented, lost, and/or entangled within the helicopter. Fifteen of these instances occurred in the absence of illumination and one with lights on.

Table 4

Mean Egress Time* for Six-man Escapes for
Each Window With and Without Illumination

Window	Lights	No Lights	Mean
1	5.31	6.24	5.77
2	1.75	2.21	1.48
3	4.38	5.65	5.01
Mean	5.72	7.05	

*Times are in seconds.

Table 5

Mean Full Flight Suite Evaluation Egress Times*
for Each Window

Window			
	1	2	3
Mean	12.85	3.01	4.57

*Times are in seconds.

In eight instances, the subjects relied on the breathing device to help them out of difficulty. Two additional attempts to use the breathing device were unsuccessful. In one of these, the subject broke the lanyard which activated the device, the second subject reported he could not find the device which was resting on his chest. The availability of a breathing device was strongly recommended by the subjects. Their mean rating on a 5-point scale of breathing device desirability was 4.0 (highly desirable).

The results obtained for the two anxiety measures were highly consistent. For both the STAI and the HRQ, the highest level of anxiety was measured on Day 1 and fell off for Days 2 and 3 (Figures 4 and 5). Night egress was somewhat less anxiety producing than day egress. This was probably a function of the experimental design which required that the subjects experience day egress before night egress. As previously indicated, the levels of anxiety experienced by the subjects were probably depressed because of the characteristics of the subject population.

Figures 6 and 7 summarize the HRQ results for each of the four periods of the escape cycle by window (escape route) and by the time of day the simulation was conducted. The highest anxiety levels were experienced during submersion and inversion of the helicopter and the lowest levels during the post-escape period. During the most anxiety producing period of the escape evolution, a subject found himself strapped to his seat

upside down. Waiting for the submersion and inversion to begin was no more anxiety producing than reaching the surface and waiting for the next trial to begin. These effects are consistent across windows and for daytime and nighttime simulations.

The most meaningful data point for evaluation of the effects of six men in the helicopter during egress is the seat to window escape time for the first man with each escape route. This data point is directly comparable to the data points obtained for the three man runs. Although the total time for an escape evolution would be expected to increase with six man escapes, the egress time for any one escape should hopefully remain unaffected. Comparing the data in Table 3 with that in Table 4, no increase in egress time is to be found for the six man runs.

Considering the data for the full suit egresses, with the exception of an increase in egress time for Window 1 which is difficult to exit from, the egress times in Table 5 are comparable to those in Table 3. There was no major effect of the flight gear on egress time. Subjects reported that although the flight gear was clumsy, it did not effect their ability to exit from the helicopter.

In summary, the results of this study indicate that hatch illumination does facilitate egress from the submerged helicopter. The effectiveness of these lights would be expected to be even greater than demonstrated here with a population of subjects who are not highly trained in underwater performance. Training, even for experienced divers, has a major effect on speed

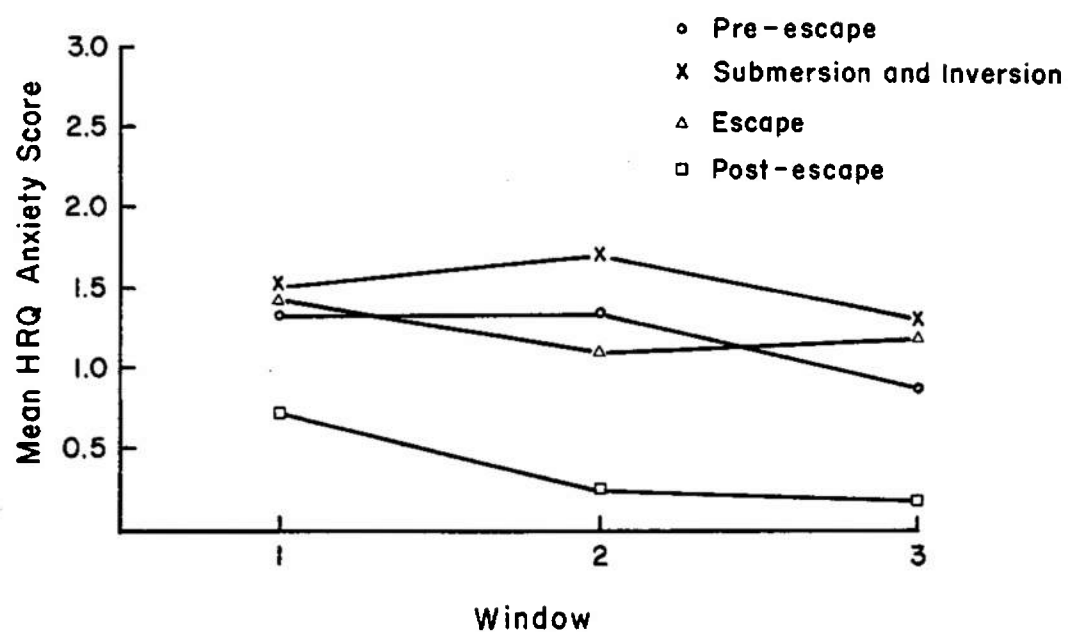


Figure 6. Mean HRQ anxiety scores for each of the four periods of the escape cycle by escape route.

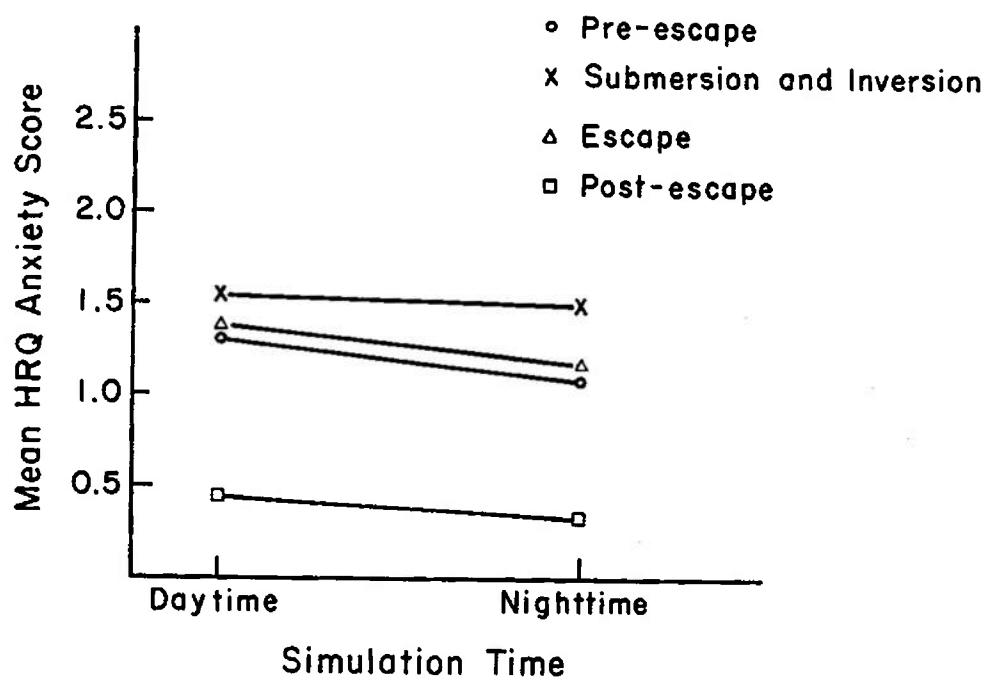


Figure 7. Mean daytime and nighttime HRQ anxiety scores for each period of the escape cycle.

of egress. Neither the presence of up to six men in the helicopter nor the fact that the escapees are wearing full flight attire has a major effect on individual egress times.

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FOOTNOTES

- ¹The lights were manufactured by Atkins & Merrill.
- ²This device was submitted for testing by the Naval Air Development Center.

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